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(54) **SUBSTRATE GRIPPER APPARATUS AND METHODS**

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B25J 15/00 (2006.01)

(52) **U.S. Cl.**
CPC ***B25J 15/0028*** (2013.01)

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USPC 294/119.1, 207, 902, 213; 414/941
See application file for complete search history.

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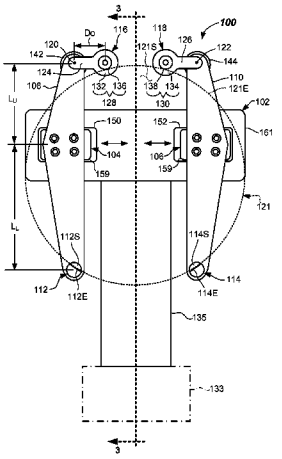
(57) **ABSTRACT**

A substrate gripper apparatus is provided. Substrate gripper apparatus includes a body, a first slide member moveable relative to the body, a first finger mounting member coupled to the first slide member, a first lower finger coupled to the first finger mounting member, and a first pivoting finger coupled to the first finger mounting member. First pivoting member may impose a force on a substrate due to gravity. Methods of operating the substrate gripper apparatus as well as other aspects are provided.

19 Claims, 6 Drawing Sheets



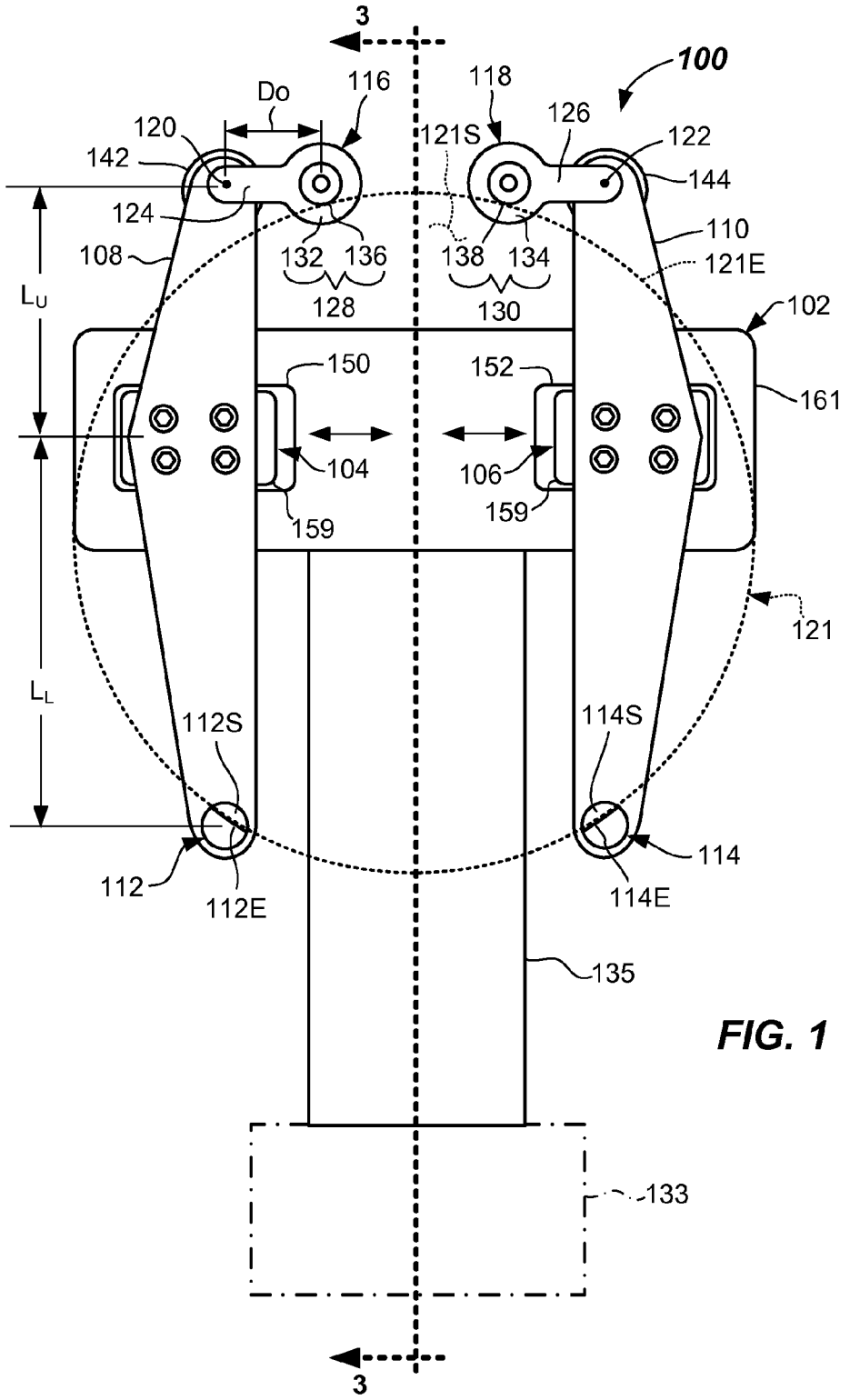

3
100
Do
116
118
120
121S
126
122
142
144
124
110
108
132
136
138
134
121E
128
130
102
L_U
150
152
161
104
106
159
159
121
L_L
112S
114S
114
112
112E
114E
135
133
3

FIG. 1

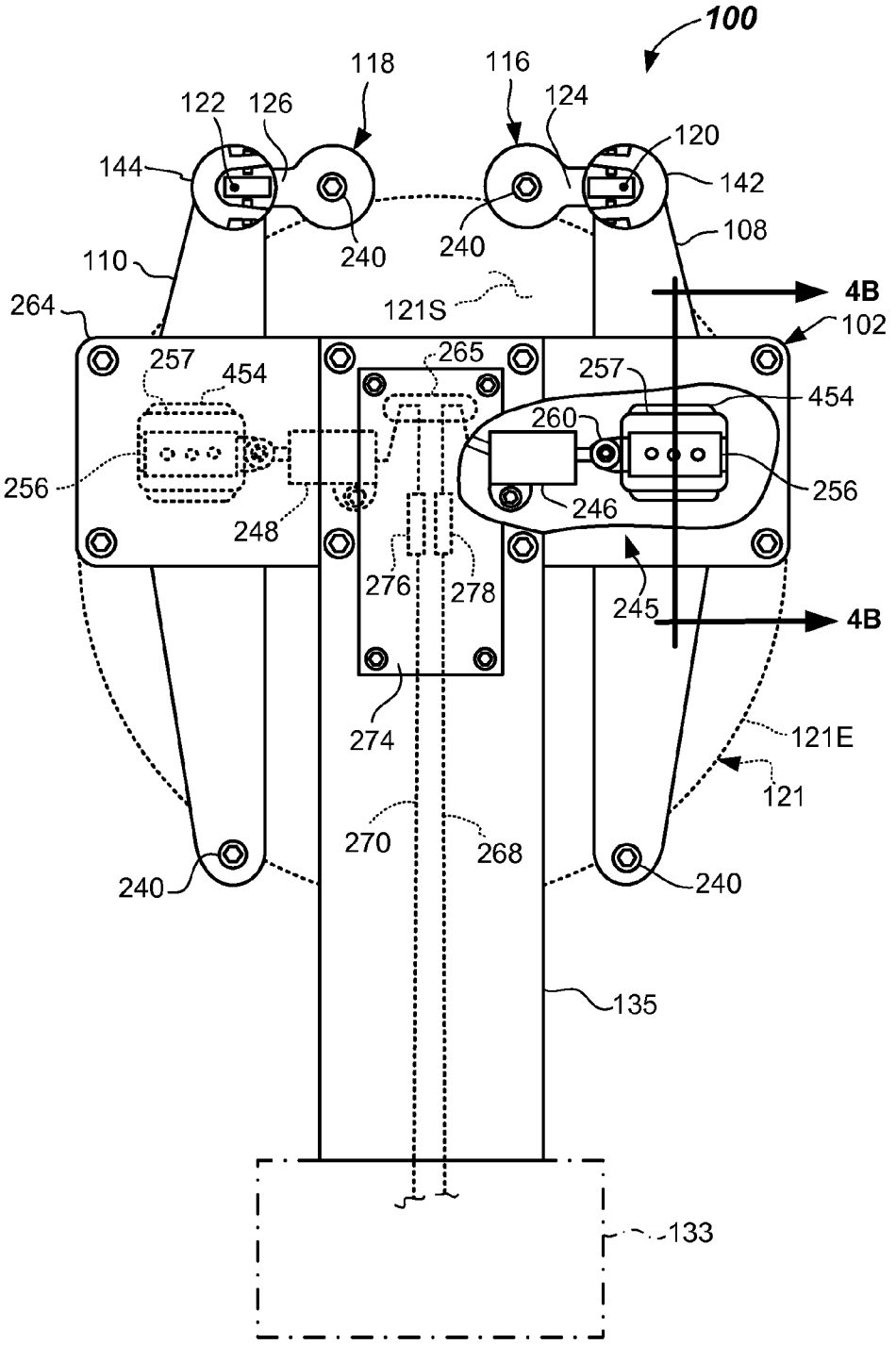

100
118
116
122
126
124
120
144
142
240
240
108
110
121S
4B
264
102
257
454
265
257
454
260
256
256
246
248
276
278
245
4B
274
121E
121
270
268
240
240
135
133

FIG. 2

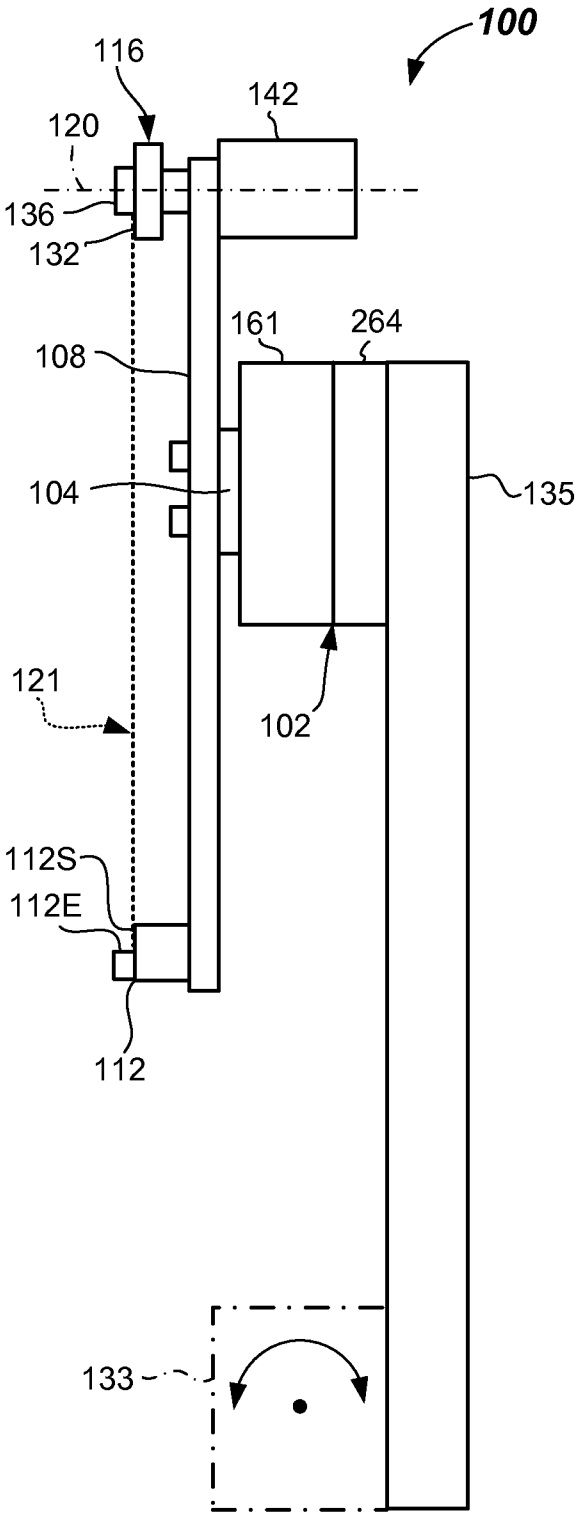

100
116
142
120
136
132
161
264
108
104
135
121
102
112S
112E
112
133

FIG. 3A

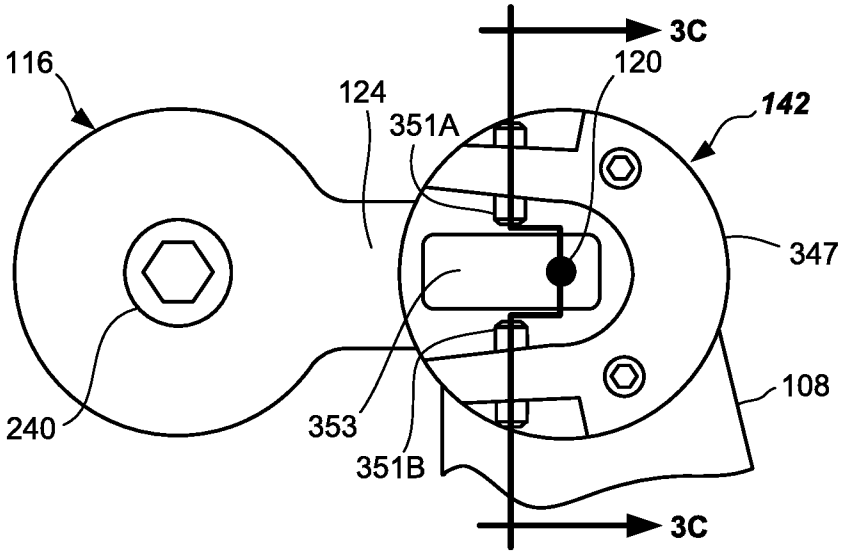

3C
116
120
124
351A
142
347
108
240
353
351B
3C

FIG. 3B

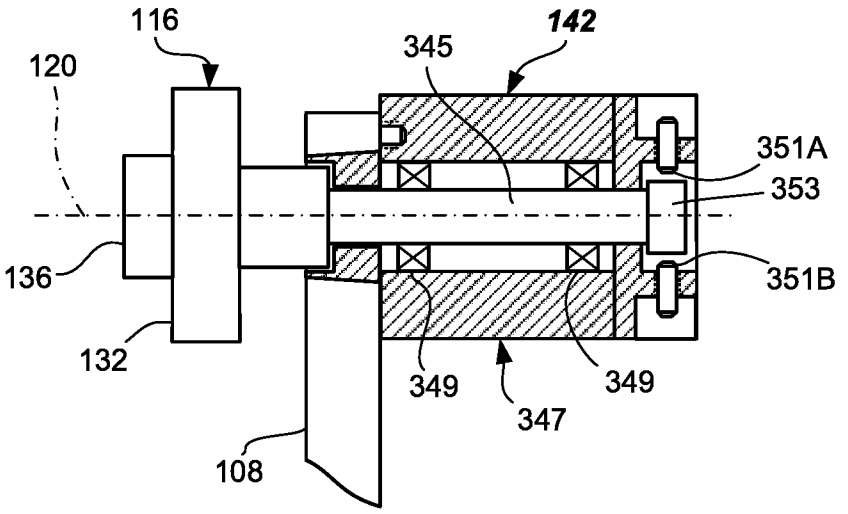

116
142
345
120
351A
353
136
351B
132
349
349
347
108

FIG. 3C

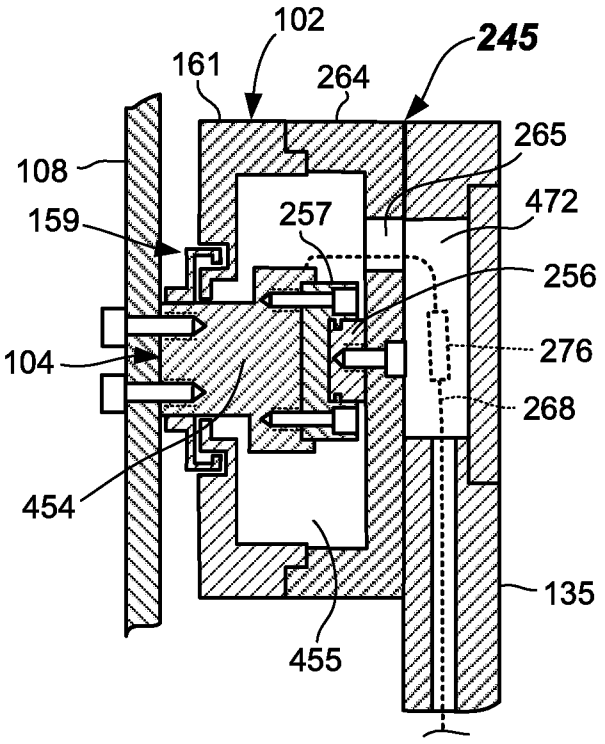

102
245
161
264
265
108
472
159
257
256
276
104
268
454
135
455

FIG. 4A

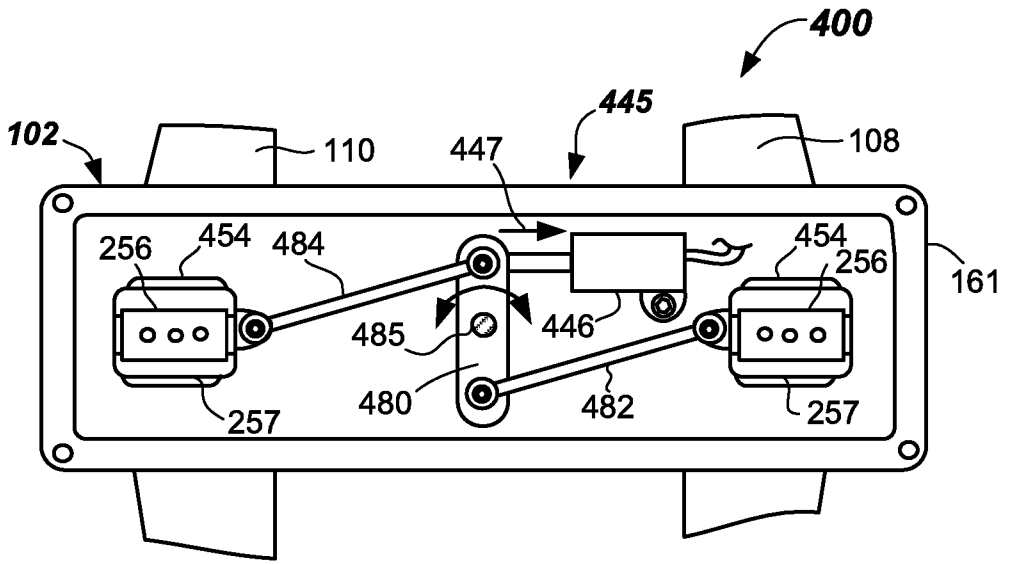

400
445
102
110
447
108
256
454
484
454
256
161
485
446
480
482
257
257

FIG. 4B

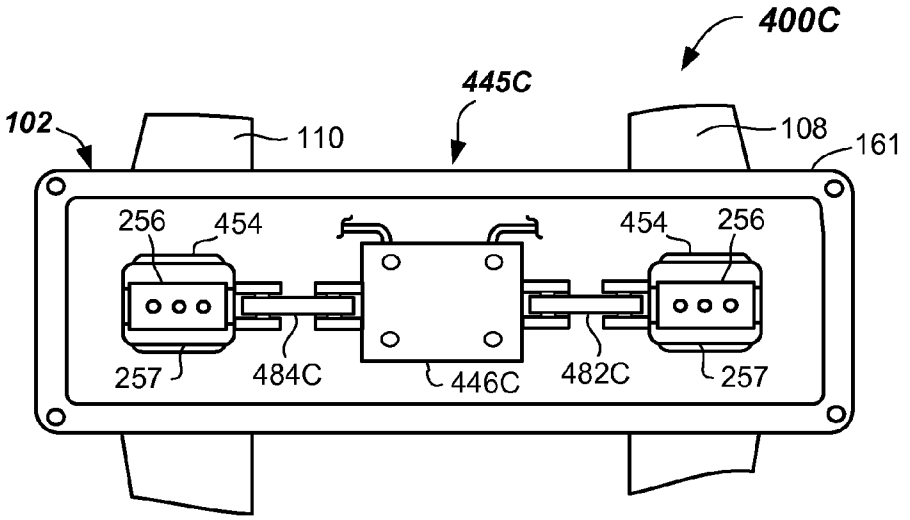

400C
445C
102
110
108
161
256
454
454
256
257
484C
446C
482C
257

FIG. 4C

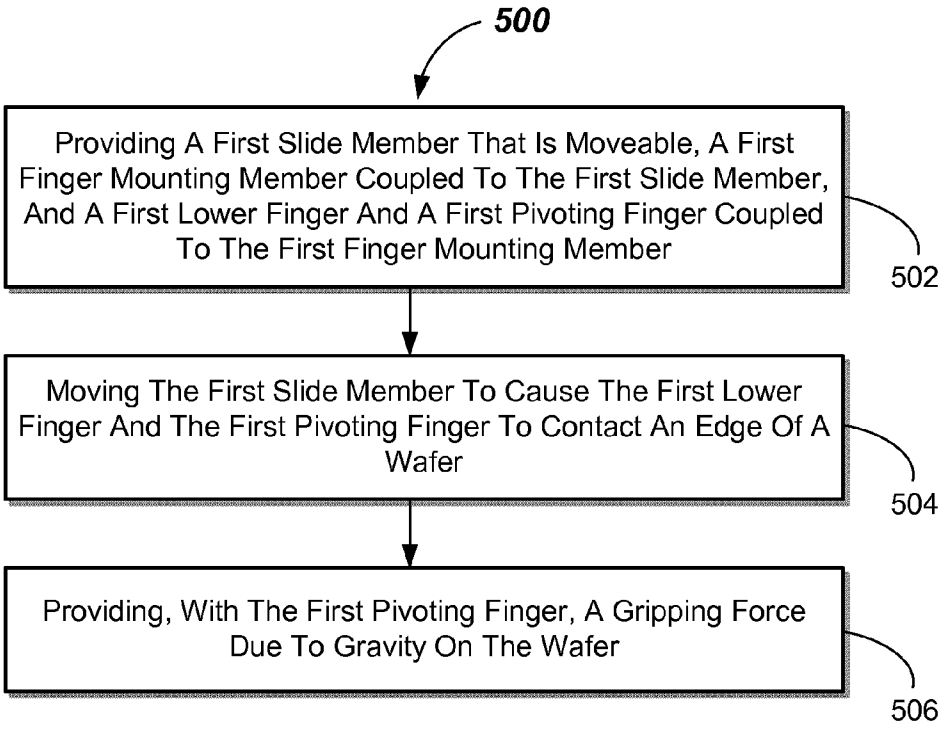

500
Providing A First Slide Member That Is Moveable, A First Finger Mounting Member Coupled To The First Slide Member, And A First Lower Finger And A First Pivoting Finger Coupled To The First Finger Mounting Member
502
Moving The First Slide Member To Cause The First Lower Finger And The First Pivoting Finger To Contact An Edge Of A Wafer
504
Providing, With The First Pivoting Finger, A Gripping Force Due To Gravity On The Wafer
506

FIG. 5

SUBSTRATE GRIPPER APPARATUS AND METHODS

FIELD

The present invention relates generally to electronic device manufacturing, and more particularly to substrate grippers.

BACKGROUND

Within electronic device manufacturing, a planarization process may be used to remove various layers or films, such as silicon dioxide, silicon nitride, copper, or the like from a substrate (e.g., a patterned substrate). Planarization may be accomplished using a chemical mechanical polishing (CMP) process by applying abrasive slurry between a polishing pad and the substrate surface to be polished (e.g., planarized).

Once the CMP process is completed on the substrate, one or more post-planarization cleaning processes may take place thereon. In some instances, post-CMP processing includes cleaning within a tank of liquid (or a bath) followed by, and possibly even preceded by, a rinsing bath (e.g., within a separate tank) to achieve desirable cleaning levels. Upon being removed from the rinsing bath, a drying apparatus (e.g., a Marangoni dryer) may be used to blow off bath fluid from a surface of the substrate.

During one or more of the cleaning processes, the substrates (e.g., substrates) may be transported and gripped by a gripper mechanism. However, existing grippers suffer from various problems. Accordingly, improved gripper apparatus adapted to grip and move substrates are sought.

SUMMARY

In one aspect, a substrate gripper apparatus is provided. The substrate gripper apparatus includes a body, a first slide member moveable relative to the body, a first finger mounting member coupled to the first slide member, a first lower finger coupled to the first finger mounting member, and a first pivoting finger coupled to the first finger mounting member.

In another aspect, a substrate gripper apparatus is provided. The substrate gripper apparatus includes a body, a first slide member and a second slide member moveable towards and away from each other, a first finger mounting member coupled to the first slide member, a second finger mounting member coupled to the second slide member, a first lower finger coupled to a lower end of the first finger mounting member, a second lower finger coupled to a lower end of the second finger mounting member, a first pivoting finger coupled to an upper end of the first finger mounting member and pivotable about a first pivot axis, the first pivoting finger including surface support features and edge support features, and a second pivoting finger coupled to an upper end of the second finger mounting member and pivotable about a second pivot axis, the second pivoting finger also including surface support features and edge support features.

In yet another aspect, a method of operating a substrate gripper apparatus is provided. The method includes providing a first slide member (e.g., that is linearly moveable), a first finger mounting member coupled to the first slide member, and a first lower finger and a first pivoting finger coupled to the first finger mounting member, moving the first slide member to cause the first lower finger and the first pivoting finger to contact an edge of a substrate, and providing, with the first pivoting finger, a gripping force due to gravity on the substrate.

Other features and aspects of the present invention will become more fully apparent from the following detailed description of example embodiments, the appended claims, and the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

The drawings, described below, are for illustrative purposes only and are not necessarily drawn to scale. The drawings are not intended to limit the scope of the invention in any way.

FIG. **1** illustrates a front view of a substrate gripper apparatus according to one or more embodiments.

FIG. **2** illustrates a rear view with a partial cutout of a substrate gripper apparatus according to one or more embodiments.

FIG. **3**A illustrates a side view of a substrate gripper apparatus according to one or more embodiments.

FIG. **3**B illustrates an end view of a pivot assembly of a substrate gripper apparatus according to one or more embodiments.

FIG. **3**C illustrates a cross-sectioned side view of a pivot assembly of a substrate gripper apparatus taken along section line **3**C-**3**C of FIG. **3**B according to one or more embodiments.

FIG. **4**A illustrates a partial side cross-sectioned view of a substrate gripper apparatus illustrating construction of a first slide member according to one or more embodiments.

FIG. **4**B illustrates a rear view (with base removed) of an alternative substrate gripper apparatus illustrating an alternative actuation assembly according to one or more embodiments.

FIG. **4**C illustrates a rear view (with base removed) of another alternative substrate gripper apparatus according to one or more embodiments.

FIG. **5** illustrates a flowchart of a method of operating a substrate gripper apparatus according to one or more embodiments.

DESCRIPTION

A substrate gripper apparatus is provided in accordance with one or more embodiments of the invention. Substrate gripper apparatus may be part of a substrate handler of a substrate cleaning module, for example. Substrate gripper apparatus has utility for accepting substrates from one location and gripping them as they are moved to another location. In particular, the substrate gripper apparatus may receive substrates from a substrate holder of a substrate cleaning module (e.g., including a rinsing bath), move the substrate to a handoff location, and position a substrate for acceptance by another robot. Substrate gripper apparatus, in one aspect, is clean, in that any particles generated by mechanical components thereof are substantially retained inside the substrate gripper apparatus. Thus, the substrate gripper apparatus minimizes particulate contamination of the substrate manufacturing environment.

Referring now to FIGS. **1**-**3**A, various views of the substrate gripper apparatus **100** are shown according to a first embodiment of the present invention. The substrate gripper apparatus **100** comprises a body **102**, and a first slide member **104** and second slide member **106** moveable towards and away from each other, and which may move linearly relative to the body **102**, and may be synchronized. First slide member **104** and second slide member **106** may be slide blocks that slide on linear bearings or other suitable bearing surfaces or mechanisms formed on, or connected to, the body **102**.

The depicted substrate gripper apparatus **100** comprises a first finger mounting member **108** coupled to the first slide member **104**, and a second finger mounting member **110** coupled to the second slide member **106**. First and second finger mounting member **108**, **110** may be coupled to respective first slide member **104** and second slide member **106** by fasteners (e.g., bolts or screws, or the like) or they may be coupled by being made integral with the first slide member **104** and second slide member **106**. Each of the first and second finger mounting members **108**, **110** includes a first end (e.g., lower end) extending below the mounting location to the respective first and second slide members **104**, **106**, and a second end (e.g., upper end) extending above the mounting location, as shown.

A first lower finger **112** may be coupled to a first end (e.g., lower end) of the first finger mounting member **108**, and a second lower finger **114** may be coupled to a first end (e.g., lower end) of the second finger mounting member **110**. The first and second lower fingers **112**, **114** may be coupled to the first and second finger mounting members **108**, **110** by fasteners **240** (e.g., bolts, screws, or the like). The first and second lower fingers **112**, **114** may include substrate surface support features, such as lower surface support features **112**S, **114**S that may be configured and adapted to contact, register, and support a planar surface of a substrate **121**, as shown. First and second lower fingers **112**, **114** may include substrate edge support features, such as lower edge support features **112**E, **114**E that may be configured and adapted to contact, register, and support a radial edge of a substrate **121**, as shown.

On an upper end, a first pivoting finger **116** may be coupled to the first finger mounting member **108**, and a second pivoting finger **118** may be coupled to an upper end of the second finger mounting member **110**. Each of the first and second pivoting fingers **116**, **118** are pivotable in operation about respective first and second pivot axes **120**, **122**. One or more embodiments may include a first pivot arm **124** and a second pivot arm **126**. Each of the first and second finger pivot arms **124**, **126** extend generally laterally from the respective first and second pivot axes **120**, **122**. First and second pivoting fingers **116**, **118** may extend towards each other from their respective first and second pivot axes **120**, **122**.

In more detail, each of the pivoting fingers **116**, **118** may include support features **128**, **130** that are offset from the respective pivot axes **120**, **122**. Support features may include surface support features, such as first and second surface supports **132**, **134** configured and adapted to contact and receive a front or back planar surface **121**S of the substrate **121**, and edge support features, such as first and second edge supports **136**, **138** configured and adapted to contact and support a radial edge **121**E of the substrate **121**. The first and second surface support features **132**, **134** may be coupled, respectively, to the first and second finger pivot arms **124**, **126**, and coupled also to the first and second edge support features **136**, **138** that may extend from the first and second surface support features **132**, **134**.

As shown, the first and second surface supports **132**, **134** may be configured to support the substrate **121** when the substrate gripper apparatus **100** is oriented horizontally, such as when the substrate gripper apparatus **100** is positioned at a handoff location to handoff a substrate **121** to another robot. The first and second surface supports **132**, **134** may each include a support surface that extends generally perpendicularly from the first and second edge supports **136**, **138**. First and second surface supports **132**, **134** may extend to at least about 5 mm from an outside edge (e.g., the edge contacting the radial edge **121**E) of the first and second edge supports **136**, **138**. In some embodiments, the first and second surface supports **132**, **134** may extend to between about 5 mm to about 25 mm from the outside edge. The first and second surface supports **132**, **134** may include a semi-circular profile as shown, and the first and second surface supports **132**, **134** may comprise a planar surface on which the substrate **121** may rest and be supported.

As shown, the first edge support **136** and second edge support **138** may be configured such that they will contact the radial edge of the substrate **121** at an offset distance "Do" that is offset from the respective pivot axes **120**, **122**. Offset distance "Do" may be between about 10 mm and about 100 mm, in some embodiments. Other offset distances may be used. The goal of the offset is to have a center of gravity of the first pivoting finger **116** (and second pivoting finger **118**) near the contact location with the first and second edge supports **136**, **138** when in a vertical orientation. First and second edge supports **136**, **138** may be circular pucks including a cylindrical outer surface adapted to contact the radial edge **121**E. First and second edge supports **136**, **138** may be attached to the body of the pivoting fingers **116**, **118** by fasteners **240**, such as bolts, screws, or the like. First and second edge supports **136**, **138** may be made from a soft polymer material, such as a thermoplastic polymer. One suitable material is a polyether ether ketone material. First and second edge supports **136**, **138** may have a diameter of between about 10 mm and about 40 mm, and about 18 mm in some embodiments and a height from the first and second surface supports **132**, **134** of at least about 1 mm, and about 6 mm, for example. Other materials and sizes may be used.

Each of the first and second pivoting fingers **116**, **118** may be coupled to a pivot assembly **142**, **144**. The pivot assembly **142** is shown in FIGS. **3**B and **3**C and operates to support a shaft **345** coupled to the pivoting finger **116**. The shaft **345** may be rotationally mounted to the pivot housing **347** by one or more bearings **349**. Pivot housing **347** may be coupled to the first finger mounting member **108**, by fasteners (e.g., bolts, screws, or the like). Rotation of the pivoting finger **116** may be limited to defined clockwise and counterclockwise rotations. The limits may be adjustable, and may be provided by one or more stops **351**A, **351**B that engage with lever **353**. Lever **353** may be rigidly mounted on, or integral with, shaft **345** and rotates therewith. Stops **351**A, **351**B may be set screws that allow adjustment of an amount of clockwise and counterclockwise rotation of the pivoting finger **116** within rotational limits. The pivot assembly **144** may be identical to pivot assembly **142**.

In some embodiments, the substrate gripper apparatus may, at times, be positioned in a horizontal orientation, and at other times be positioned in a vertical orientation (shown in FIGS. **1**-**3**A). In the vertical orientation, the first slide member **104** and second slide member **106** may be moved apart from one another to accept a substrate **121**. The first slide member **104** and second slide member **106** may be moved apart (and towards each other) a distance under the action of one or more actuators (e.g., first and second actuators **246**, **248**).

In some embodiments, hard or soft stops may be provided to limit an extent that the first slide member **104** and second slide member **106** may move apart and/or together. For example, first slide member **104** and second slide member **106** may be received in first and second pockets **150**, **152**, and may only open so far until contact with an outside edge of the first and second pocket **150**, **152** is made. The substrate **121** may then be placed onto the surface support features **132**, **134** of the first and second pivoting fingers **116**, **118** and onto the surface support features **112**S, **114**S of the first and second lower fingers **112**, **114**. Once positioned, the first slide member **104** and second slide member **106** may be closed via

action of the one or more actuators (e.g., first and second actuators **246**, **248**), which may bring the edge support features (e.g., **112**E, **114**E, **136**, **138**) in contact with the radial edge **121**E of the substrate **121**.

The substrate gripper apparatus **100** may then be transitioned from the vertical orientation to a horizontal (upright) orientation in some embodiments. Transitional rotation may be provided via the action of a rotation mechanism **133**, which may be coupled to the riser **135**, which is in turn coupled to the body **102** of the substrate gripper apparatus **100**. Upon moving the first slide member **104** and second slide member **106** towards each other a vertical orientation (closing), the first and second pivoting fingers **116**, **118** may contact the radial edge **121**E of the substrate **121**, may pivot upward slightly, and provide a gripping force due to the force of gravity. In particular, the first and second edge support features **136**, **138** come into contact with, and apply the gripping force, to the radial edge **121**E of the substrate **121**. This gripping force pinches the substrate **121** between the first and second pivoting fingers **116**, **118** and the first and second lower fingers **112**, **114**, and, thus, holds the substrate **121**. In some embodiments, the moment that is provided by each of the first and second pivoting fingers **116**, **118** on the substrate **121** may be greater than about 0.01 in-lbs., or even between about 0.05 and about 1 in-lbs., and about 0.18 in-lbs. in some embodiments.

In operation, the first and second slide members **104**, **106** may be linearly moveable by an actuation assembly **245** including one or more actuators (e.g., first actuator **246** and second actuator **248**). The first and second actuators **246**, **248** may be any suitable type of actuator, such as an air cylinder actuator, linear electric actuator, hydraulic actuator, or the like. Other suitable actuators, even rotary actuators, may be adapted to use. However, the motion of the actuators **246**, **248** should be synchronized, i.e., substantially equal upon opening and closing. The linear constraints to movement of the first slide member **104** and second slide member **106** may be provided by any suitable slide bearing assembly construction.

One example slide bearing construction is shown in FIG. **2** and in partial cross-section in FIG. **4**A. First slide member **104** shown includes a frontal member **454** coupled to the first finger mounting member **108** and backing member **256**. Backing member **256** may be rigidly fastened to a base **264** of the body **102**, such as by fasteners (e.g., bolts, screws, or the like). Base **264** and cover **161** may form the body **102**, which may include a step interconnection between them to minimize particle escape from a chamber **455** formed by them. Frontal member **454** is able to freely slide laterally, as shown, relative to the backing member **256**. Frontal member **454** may be coupled to a bearing component **257**. Bearing component **257** may include bearing features that complement bearing features included on backing member **256**. Bearing features may be engaged with one another to accommodate linear relative sliding motion there between. Each of the bearing features may be dimensioned so as to provide a close sliding fit and provide ease of linear sliding motion. A seal **159** (e.g., a labyrinth seal as shown in FIGS. **1** and **4**A) may be provided between the cover **161** and the frontal member **454**, which includes a torturous path to minimize generated particle escape.

As shown in FIGS. **2** and **4**A, the frontal members **454** may be coupled to ends **260** (e.g., spherical rod ends or the like), which may be provided on an end of a shaft of each the first and second actuators **246**, **248**. Other types of connectors suitable for attachment of the actuators **246**, **248** to the frontal members **454** may be used. Optionally, ends **260** may be coupled to bearing components **257**. Driving the frontal members **454** (or optionally, the bearing components **257**) with the first and second actuators **246**, **248** opens and closes the first and second finger mounting members **108**, **110**.

The cover **161** may be coupled to the base **264**, such as by fasteners (e.g., bolts, screws, or the like) to form the chamber **455**, and to cover the internal components of the substrate gripper apparatus **100** contained therein. Cover **161** may be configured and operative to contain any particles generated by movement of the actuation assembly **245** therein. Likewise, a seal **159** (FIGS. **1** and **4**A) may be provided between the first slide member **104** and the body **102** to catch and/or retain any generated particles. A like seal **159** may be provided between the second slide member **106** and the body **102**.

Riser **135** may be coupled to the base **264** or elsewhere on the body **102**, such as by fasteners (e.g., by bolts, screws, or the like). Base **264** may include an aperture **265** formed therein that may be configured and adapted to allow first line **268** and second line **270**, such as electrical cables, or air or hydraulic lines from the first and second actuators **246**, **248** (depending on whether electrical, pneumatic, or hydraulic) to pass through into a access chamber **472** (FIG. **4**A) that may be formed in the riser **135**.

First and second lines **268**, **270** may connect to a fluid supply (not shown) to provide a pressurized fluid or a driver (not shown) to provide electric power to the first and second actuators **246**, **248**, depending on whether the actuators are pneumatic, hydraulic, or electrical. Additional lines may be provided for position sensors (not shown) that are configured to sense opening and closing. A plate **274** may cover the access chamber **472** and allow access to first and second connectors **276**, **278** in order to allow a quick connect/disconnect of the substrate gripper apparatus **100** to and from the riser **135**.

FIG. **4**B illustrates a partial rear view of an optional embodiment of an actuation assembly **445** that may be used to accomplish the open and close motion of the substrate gripper apparatus **400**. The other components are the same as described with reference to FIGS. **1**-**4**A. In the depicted embodiment of FIG. **4**B, a single actuator (e.g., actuator **446**) may be used to actuate the bearing components **257**, and, thus, move the first slide member **104** and second slide member **106**. Actuator **446** may be coupled to a pivoting link **480** along with first and second linkages **482**, **484**. Pivoting link **480** is configured to freely pivot about a pivot **485** on the base **264**. In operation, actuation of the actuator **446** in the direction of arrow **447** causes closure, that is, movement of the bearing components **257** (and the first and second slide members **104**, **106**) towards each other. Actuation in the opposite direction causes opening, i.e., movement of the first slide member **104** and second slide member **106** away from each other.

Spring biasing may be provided in some embodiments (not shown) to bias the first and second finger mounting members **108**, **110** to a normally-opened orientation, or even a normally-closed orientation, as desired. For example, a spring (not shown) may be mounted to either side of the pivoting link **480** and also to the base **264**.

In another actuation assembly option for the substrate gripper apparatus **400**C, as shown in FIG. **4**C, a actuator **446**C (e.g., a single actuator) is used. In this configuration, actuation assembly **445**C may include first and second linkages **482**C, **484**C coupled between the frontal members **454** and the actuator **446**C, respectively. Actuator **446**C may be coupled to the base **264** (removed in FIG. **4**C for clarity) by fasteners (e.g., bolts, screws, or the like). Direct actuation of actuator **446**C causes motion of the frontal members **454**

towards and away from each, and thus motion of the first and second sliding members **104**, **106** towards and away from one another. Actuator **446**C may be a dual-acting actuator (e.g., a dual acting pneumatic actuator), for example. Each side of the actuator **446**C may be operated in synchronism.

In yet another aspect, a method of operating a substrate gripper apparatus (e.g., substrate gripper apparatus **100**, **400**, **400**C) is provided. The method **500** includes, in **502**, providing a first slide member (e.g., first slide member **104**) that is moveable (e.g., linearly), a first finger mounting member (e.g., first finger mounting member **108**) coupled to the first slide member (e.g., first slide member **104**), and a first lower finger (e.g., first lower finger **112**) and a first pivoting finger (e.g., first pivoting finger **116**) coupled to the first finger mounting member (e.g., first finger mounting member **108**).

The method **500** includes, in **504**, moving the first slide member (e.g., first slide member **104**) to cause the first lower finger (e.g., first lower finger **112**) and the first pivoting finger (e.g., first pivoting finger **116**) to contact an edge (e.g., radial edge **121**E) of a substrate (e.g., substrate **121**).

The method **500** includes, in **506**, providing, with the first pivoting finger (e.g., first pivoting finger **116**), a gripping force due to gravity on the substrate (e.g., on substrate **121**).

While the present invention has been disclosed in connection with the preferred embodiments thereof, it should be understood that other embodiments may fall within the scope of the invention, as defined by the following claims. For example, although the substrate gripper apparatus **100**, **400** described herein have a first slide member **104** and a second slide member **106** that are moveable relative to the body **102**, the invention will also work if one side of the substrate gripper were to be fixed, and thus only the first slide member **104** or only the second slide member **106** may be moveable.

The invention claimed is:

1. A substrate gripper apparatus, comprising:
- a body;
- a first slide member moveable relative to the body;
- a first finger mounting member coupled to the first slide member;
- a first lower finger coupled to the first finger mounting member; and
- a first pivoting finger coupled to the first finger mounting member
- wherein the first pivoting finger comprises a surface support feature configured and adapted to receive and support a planar surface of a substrate, and an edge support feature configured and adapted to contact and support an edge surface of the substrate.

2. The substrate gripper apparatus of claim **1**, wherein the first slide member is moveable by an actuator.

3. The substrate gripper apparatus of claim **1**, wherein the first pivoting finger comprises a rotational axis and the surface support feature and edge support feature are offset from the rotational axis.

4. The substrate gripper apparatus of claim **1**, wherein the first pivoting finger comprises a first finger pivot arm extending from a first rotational axis, the surface support feature coupled to the first finger pivot arm, and the edge support feature extending from the surface support feature.

5. The substrate gripper apparatus of claim **4**, wherein the surface support feature comprises a planar surface configured to support the planar surface of a substrate.

6. The substrate gripper apparatus of claim **4**, wherein the edge support feature comprises a cylindrical surface configured to support the radial edge of a substrate.

7. The substrate gripper apparatus of claim **1**, wherein when the substrate gripper apparatus is positioned in an upright configuration, the first pivoting finger supplies a downward force due to gravity on a substrate.

8. The substrate gripper apparatus of claim **1**, comprising:
- a second slide member;
- a second finger mounting member coupled to the second slide member;
- a second lower finger coupled to the second finger mounting member; and
- a second pivoting finger coupled to the second finger mounting member.

9. The substrate gripper apparatus of claim **1**, wherein the body comprises a base and a cover, and an actuator is coupled to the first slide member and housed in a chamber formed by the base and the cover.

10. A substrate gripper apparatus, comprising:
- a body;
- first slide member and second slide member moveable towards and away from each other;
- a first finger mounting member coupled to the first slide member;
- a second finger mounting member coupled to the second slide member;
- a first lower finger coupled to a lower end of the first finger mounting member;
- a second lower finger coupled to a lower end of the second finger mounting member;
- a first pivoting finger coupled to an upper end of the first finger mounting member and pivotable about a first pivot axis, the first pivoting finger including surface support features and edge support features; and
- a second pivoting finger coupled to an upper end of the second finger mounting member and pivotable about a second pivot axis, the second pivoting finger also including surface support features and edge support features.

11. The substrate gripper apparatus of claim **10**, wherein the first pivoting finger and the second pivoting finger extend towards each other from the first pivot axis and the second pivot axis, respectively.

12. The substrate gripper apparatus of claim **10** wherein the first lower finger and the second lower finger are configured with surface support surfaces adapted to support a planar surface of a substrate.

13. The substrate gripper apparatus of claim **10** wherein the first lower finger and the second lower finger are configured with edge support surfaces adapted to contact and support a radial edge of a substrate.

14. The substrate gripper apparatus of claim **10**, comprising an actuation assembly coupled to the first slide member and second slide member.

15. A method of operating a substrate gripper apparatus, comprising:
- providing a first slide member that is moveable, a first finger mounting member coupled to the first slide member, and a first lower finger and a first pivoting finger coupled to the first finger mounting member wherein the first pivoting finger comprises a surface support feature configured and adapted to receive and support a planar surface of a substrate, and an edge support feature configured and adapted to contact and support an edge surface of the substrate;
- moving the first slide member to cause the first lower finger and the edge support feature of the first pivoting finger to contact an edge of a substrate; and
- providing, with the first pivoting finger, a gripping force due to gravity on the substrate.

16. The method of claim 15, comprising supporting a substrate on support surfaces of the first lower finger and the surface support feature of the first pivoting finger when in a horizontal orientation.

17. The method of claim 15, comprising supporting the substrate in a vertical orientation.

18. The method of claim 15, comprising:

providing a second slide member, a second finger mounting member coupled to the second slide member, and a second lower finger and a second pivoting finger coupled to the second finger mounting member; and

moving the second slide member relative to the first slide member to close the substrate gripper apparatus.

19. The method of claim 18, comprising:

providing, with the second pivoting finger, a gripping force due to gravity on the substrate.

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